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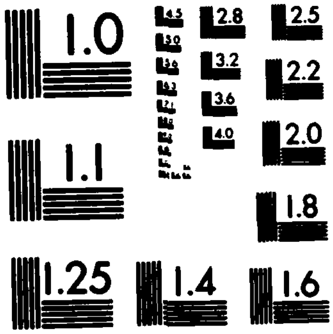
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LABORATORY NOTE NO. 84-47

CHANGES IN RHESUS CONTRAST SENSITIVITY ASSOCIATED WITH LASER INDUCED PUNCTATE FOVEAL LESIONS

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FEBRUARY 1984

LETTERMAN ARMY INSTITUTE OF RESEARCH
PRESIDIO OF SAN FRANCISCO, CALIFORNIA 94129

Changes in Rhesus Contrast Sensitivity associated with Laser-induced Punctate Foveal Lesions--Zwick and Bloom

In conducting the research described in this report, the investigation adhered to the "Guide for the Care and Use of Laboratory Animals," as promulgated by the Committee on Revision of the Guide for Laboratory Animal Facilities and Care, Institute of Laboratory Animal Resources, National Research Council.

Edwin S. Beatrice 23 Feb 84

(Signature and date)

ABSTRACT

The effects of small, punctate foveal laser exposures on rhesus spatial contrast sensitivity were investigated. The immediate effects of such exposure revealed generalized depression in sensitivity that was transient and nearly uniform across the measured spatial frequency spectrum. Funduscopic observation revealed punctate lesioned areas in the foveal-macular region of all animals following exposure. While long-term effects on high spatial frequency contrast sensitivity were virtually nonexistent, changes in the slope of the spatial contrast sensitivity function suggested the presence of residual alteration of foveal spatial vision.

Key Words: Contrast sensitivity, laser, rhesus, retinal neural interaction, foveal lesions, transient and long-term change.

CHANGES IN RHESUS CONTRAST SENSITIVITY ASSOCIATED WITH LASER INDUCED PUNCTATE FOVEAL LESIONS

Foveal integrity has been assumed to be integral with fine spatial vision. Many investigations (1,2) have demonstrated significant loss in fine spatial vision when the entire fovea was damaged. It has been assumed that function in the parafovea or more peripheral retina remains unchanged, although the recovery from such foveal damage has been postulated to involve dynamic reorganization of the structure of the retina (3). Several investigations have been conducted where lower level retinal exposures (at doses that were not totally destructive) have been used over the entire retina (4) or over the fovea (5). Results suggesting possible alteration of the lateral neural connections between fine foveal receptive fields and coarser parafoveal receptive fields were found. Kelly (6) has reported similar interaction between the fovea and the periphery in a study which used a stabilized retinal image producing an artificial foveal scotoma. It is possible that secondary foveal retinal damage mechanisms could not be elucidated in studies where the entire foveal region underwent gross damage. The importance of such microretinal functional damage processes must be considered in the genesis of macular retinal dysfunction.

In the present study we investigated the effects of intense small spot laser exposures that were placed in the fovea by behavioral procedures (7). We have examined the rhesus contrast sensitivity function to determine how such exposures, capable of producing small foveal lesions, might alter visual function over a broad range of spatial frequencies for both transient and long-term observations. Our purpose was to study the neural interrelationships that might be altered permanently from microfoveal retinal damage, under conditions that did not mask out this more subtle type of foveal damage.

METHODS

Four rhesus monkeys (Macaca mulatta) were trained on a Landolt ring visual acuity task (8,9) in which exposure to a laser flash (532 nm) could be administered during task performance (1,10). Briefly, this behavioral procedure required the animals to depress a response lever and hold it down for a variable period (< 3 seconds) before an acuity target (either a Landolt ring, or a gapless ring) appeared on a rear-projection tangent screen facing the monkey. If the

animal released the response lever following the offset of the acuity target (500 msec) two additional response panels were illuminated, displaying a Landolt ring and a gapless ring. For liquid reinforcement the animal was required to make a forced choice matching response to the previous stimulus, on the appropriate panel. Correct responses caused subsequent targets to be presented at reduced contrast levels, while incorrect responses resulted in increased target contrast on the next trial. Target contrast was controlled by the use of circular neutral density wedges.

Spatial vision thresholds (achromatic contrast sensitivity) were determined by an up-and-down method (11), allowing rapid determination of threshold. Animals were trained to yield highly stable baselines with minimal variation across sessions. Stability criterion of approximately 0.2 to 0.4 log units in contrast sensitivity maintained over a 30 to 60-minute period was generally required before any animal was considered ready for exposure. Contrast sensitivity functions from 38.5 (20/15) to 2.2 (20/267) cycles per degree were then measured for these animals. A 0.75 minute of arc gap in a Landolt ring is approximately equal to 38 cycles per degree. In one animal, pre-exposure measurements of contrast sensitivity were extended over an 18-month period. No systematic changes in sensitivity or in the shape of the contrast sensitivity function itself were observed over this period.

Small spot (50 microns) visible laser (532 nm) exposure was used to examine alterations in contrast sensitivity. The average calculated total intraocular energy (TIE) per pulse was 1.1 microjoules, assuming a 3-mm pupil in the contrast sensitivity tests employing a 70-80 ft-L achromatic background. This energy level is within the threshold region for producing retinal burns minimally visible with an ophthalmoscope.

The effect of laser exposure was determined on one of six spatial frequencies per session. All exposures were made with the flash presented through the gap in a 0.78 minute of arc (20/15) Landolt ring to affect foveal exposure. For all animals, three to four exposure sessions were given to establish reliability at a given spatial frequency.

All animals had pretraining refractive errors of less than 0.05 diopter; all had normal appearing fundi prior to exposure. Fundi of exposed animals were reexamined after the entire exposure series was completed for the animal.

RESULTS

Recovery of contrast sensitivity following laser exposure for a large target (20/267 or 2.2 cycles/degree) and a small target (20/15 or 38.5 cycles/deg) is shown in Figure 1. The ordinate represents the

percent deficit of postexposure sensitivity relative to that session's baseline sensitivity prior to exposure. Sensitivity averaged over 2-

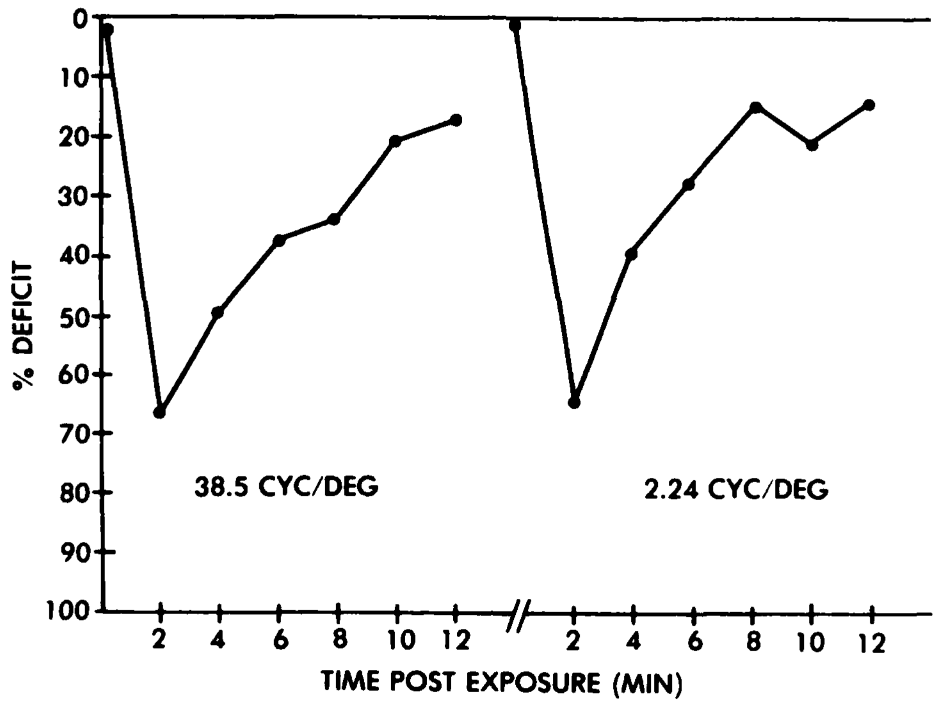

Figure 1. **Sample postexposure curves from one animal at two spatial frequencies show equivalent recovery curves after exposure. At 12 minutes both spatial frequencies have recovered to about 80 % of baseline sensitivity.**

minute blocks following exposure shows similar transient changes for large and small targets, both in maximum deficit and time course of recovery to baseline. Figure 1 shows recovery functions for a single animal, however the results are representative of the transient deficits observed for all subjects.

Data derived from recovery curves, as seen in Figure 1, for each of the four animals was used to examine the transient effects of flash exposure across the spatial frequency spectrum. Mean contrast sensitivity at 2, 6, and 16 minutes postexposure, across all exposure sessions for each spatial frequency, was compared to the mean of the session baselines for each frequency (Fig. 2). For each of the four animals, the decrease in contrast sensitivity appears to be uniform across spatial frequencies. Both small and large targets showed little recovery during the first 2 to 4 minutes postexposure. After the initial 4 minutes postexposure, full recovery was evident at 16 minutes.

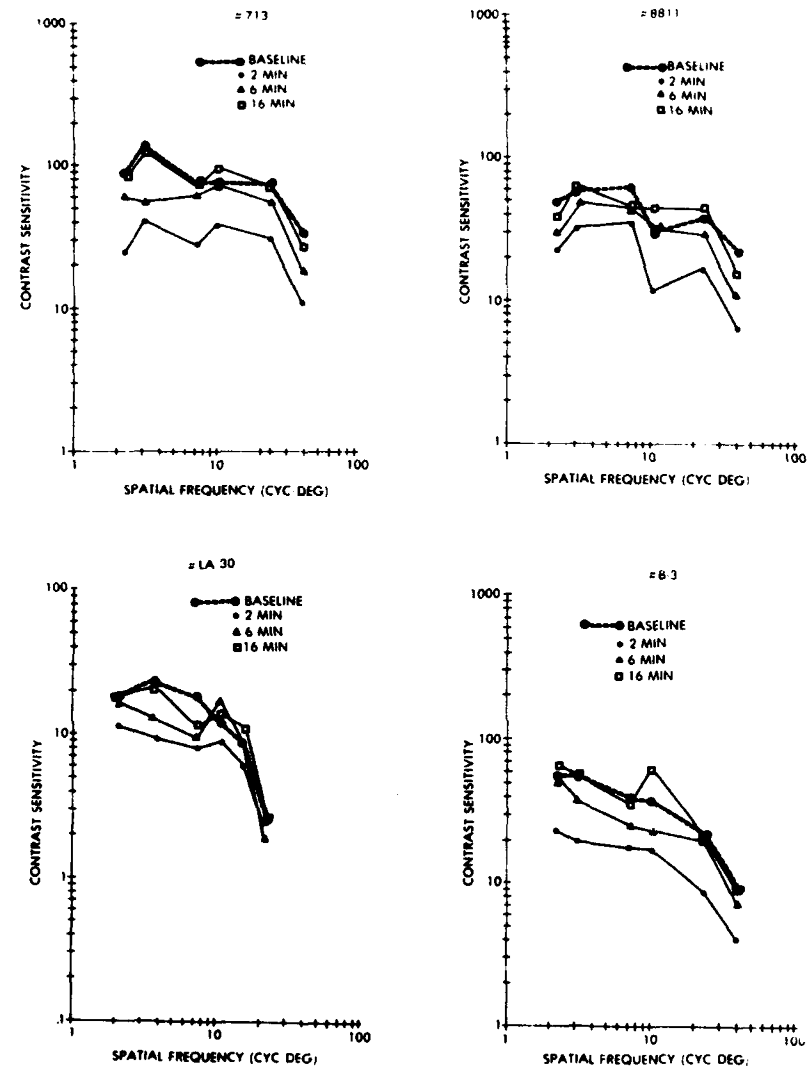

Figure 2. Transient changes in contrast sensitivity for four animals. In all animals, contrast sensitivity at 2 minutes postexposure was uniformly depressed across spatial frequency spectrum. Similar functions are shown at 6 and 16 minutes for each animal. Recovery for middle spatial frequencies over this time period appeared to be more rapid than that observed for the low and high spatial frequencies.

Long-term effects of these near threshold small spot burns were not readily apparent following daily exposures. Recovery to pre-exposure contrast sensitivity usually occurred within the same session in which exposure was administered. However, examination of the full spectrum contrast sensitivity function after several such exposure sessions, compared to similar functions obtained prior to any

exposure (Fig. 3), showed a steepening of the slope for three of our four contrast sensitivity animals. This steepening involves an increase in contrast sensitivity for larger spatial frequencies with minimal change in the finer spatial frequencies tested. These effects,

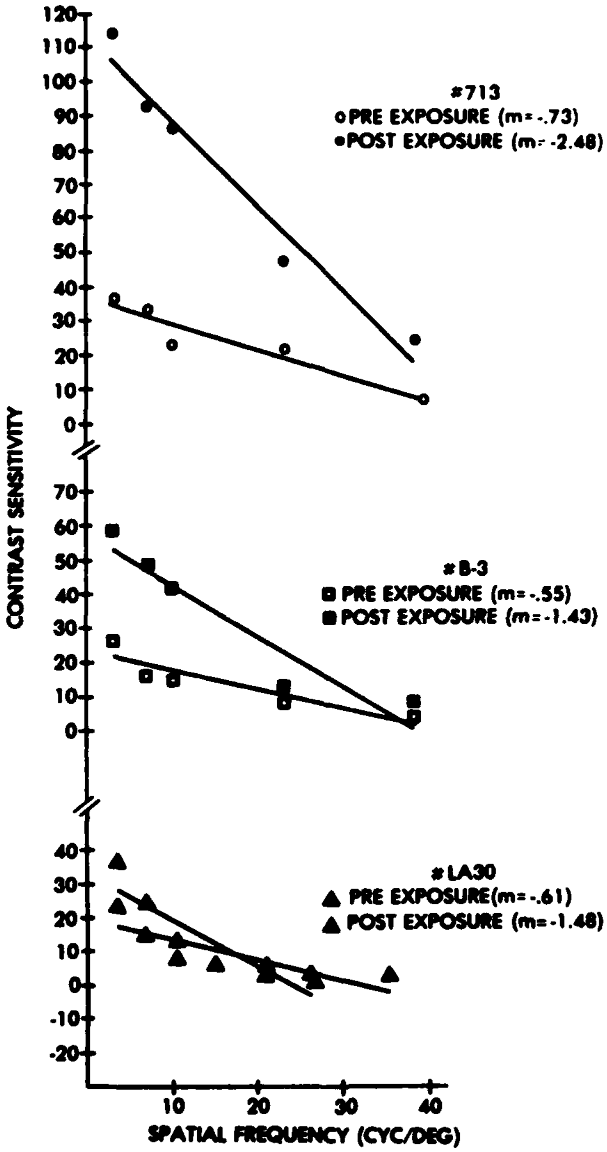

Figure 3. **Comparisons of contrast sensitivity slopes (solid lines) measured before and after the start of laser exposure with functions determined following cumulative exposure. The slopes were determined by a linear regression using least squares fit method. In all cases, postexposure slopes (denoted in Fig. 3 by "m") were steeper than those for the preexposure functions. The correlation coefficients for the three animals computed for both the preexposure and post-exposure sensitivity functions ranged between -0.88 and -0.95.**

however, would be virtually undetectable if only the highest spatial frequency or high contrast acuity were examined alone.

The relationship between contrast sensitivity slopes , before any laser exposure and postexposure, shown for the three animals in Figure 3 was not obtained in a fourth animal. In this animal (#8811) the slope of the postexposure contrast sensitivity function was similar to the pre-exposure slope, and her postexposure sensitivity appeared depressed across the entire spatial frequency spectrum. This animal had a higher pre-exposure contrast sensitivity function than the other three animals.

Fundus observations of animals examined after the completion of all laser exposure sessions revealed small punctate lesions in the foveal areas including the foveola, the central portion of the fovea. These observed lesions were consistent in size with minimal spot (20 to 50 microns) retinal exposures (12). A fundus photograph taken from one animal is shown in Figure 4.

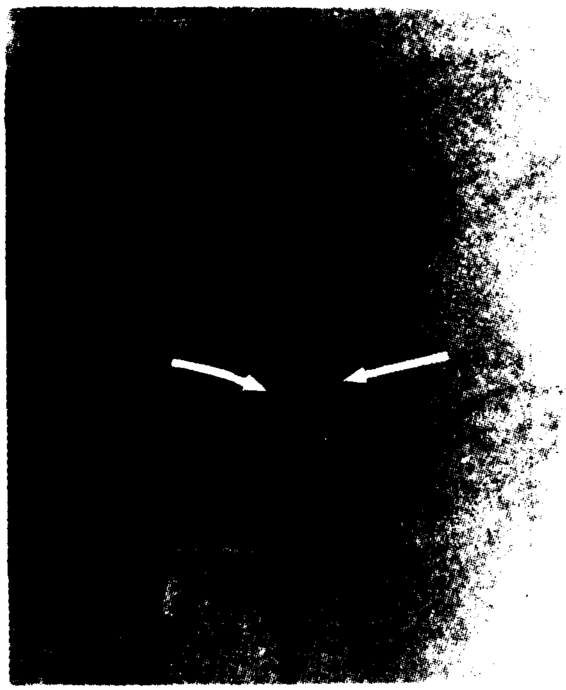

Figure 4. **Rhesus fundus photograph showing punctate lesions. Arrows indicate the location of the cluster lesions.**

DISCUSSION

We observed two effects of intense small spot, visible laser foveal exposure on contrast sensitivity that were not unrelated. First, such exposure produced a generalized effect across a broad range of spatial frequencies. Small spot foveal exposure appeared to desensitize foveal areas that must be involved with both fine as well as more coarse spatial frequency analysis. Such desensitization may take place through lateral connections within the retina. It may be induced by the energy levels utilized, although a thermal explanation may not be sufficient because threshold burns were produced approximately 50 percent of the time. Nevertheless, these exposures were extremely intense and may have been especially effective because they were small enough to fall within the receptive fields of the foveal photoreceptors thereby eliminating the possible neural cancellation that exposure of multiple receptive fields might produce (13,14). Furthermore, if conventional scatter hypotheses are used to account for the transient changes, one would expect the greatest threshold elevations in the high spatial frequencies. To the contrary, initial deficits appear uniform across the spatial frequency spectrum. With recovery, the middle frequency tests often recovered earlier than lower frequency targets, a fact inconsistent with the concept of decreased intensity of scattered light with distance from the sight of exposure.

Second, the slow but apparent shift in contrast sensitivity slope may reflect an alteration in the neural interactions that exist between foveal receptive fields and parafoveal receptive fields. As punctate lesions are amassed in the fovea, the normal inhibitory influence of the foveal neural net on parafoveal neural activity is weakened, thus enhancement of contrast sensitivity observed for our larger spatial frequencies is produced. Similar remote enhancement on contrast sensitivity has been suggested by DeValois (15) in a study of spatial frequency adaptation. In that study, temporary enhancement in spatial contrast sensitivity was maximum at spatial frequencies in excess of 2 octaves above or below the adapting spatial frequency. The result of the enhancement may be to forestall serious visual loss even though damage has occurred in the central retina. How much alteration must occur before such compensation finally breaks down? Due to the minimal area of fovea involved in each lesion it can be presumed that relatively few units tuned to high spatial frequencies are damaged with each exposure. The fact that the enhancement of low spatial frequency sensitivity occurs after multiple exposures may indicate that numerous high frequency units must be involved before there is sufficient disinhibition to produce enhancement. In experiments where larger foveal laser flash exposure was used, presumably involving most elements within the fovea, permanent loss in foveal function was more readily apparent after a single exposure (5). If the degree of foveal involvement is

a more critical factor than punctate damage to relatively small foveal retinal areas, then continued monitoring of foveal visual function should eventually reveal more permanent high-frequency spatial vision loss. The change in the slope of the contrast sensitivity function suggests that the visual system can compensate to a limited degree for frank foveal retinal tissue damage.

CONCLUSIONS

We suggest first, that the broad transient spatial frequency effects are a consequence of neural interactions that may be stressed due either to frank retinal damage to foveal receptive field organization or to intense but nondestructive exposure of the fovea. Second, as foveal tissue damage was actually amassed, we observed a change in the slope of the contrast sensitivity function. The importance of measuring this function (16) is highlighted by this finding, because strict observation of a single point alone (such as measurement of clinical acuity alone) would not have indicated any change in function. The change in slope suggests a reorganization of foveal and extrafoveal neural influence which may continue to change with additional exposures. The change in sensitivity for large targets before any reduction in sensitivity for the fine acuity targets suggests that measurement of contrast sensitivity may provide an early warning of possible foveal damage.

RECOMMENDATIONS

Laser safety must be considered in military applications of lasers. Serious hazards to vision may well go undetected because of the lack of field clinical vision and ophthalmological tests to detect subtle but significant visual damage. The use of measures of contrast sensitivity, as well as other visual tests sensitive to early retinal damage, is recommended as a routine screening test for troops at risk of exposure to potentially hazardous laser light, either in the combat or in training scenarios.

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